

Attorney Docket No.: 0180214

In the Claims:

Claim 1 (currently amended): A method of fabricating a semiconductor device, having a reduced-oxygen copper-zinc alloy (Cu-Zn) thin film formed on a copper (Cu) surface by electroplating the Cu surface in a chemical solution, comprising the steps of:

~~providing~~forming a semiconductor substrate having a Cu surface on a semiconductor substrate;

providing a chemical solution;

electroplating the Cu surface in the chemical solution, thereby forming a Cu-Zn alloy thin film on the Cu surface, wherein the Cu-Zn alloy thin film completely covers the Cu surface;

rinsing the Cu-Zn alloy thin film in a solvent;

drying the Cu-Zn alloy thin film under a gaseous flow;

annealing the Cu-Zn alloy thin film formed on the Cu surface, thereby forming a reduced-oxygen Cu-Zn alloy thin film; and

completing formation of the semiconductor device.

Claim 2 (original): A method, as recited in Claim 1,

wherein the chemical solution is nontoxic and aqueous, and

wherein the chemical solution comprises:

at least one zinc (Zn) ion source for providing a plurality of Zn ions;

Attorney Docket No.: 0180214

at least one copper (Cu) ion source for providing a plurality of Cu ions;
at least one complexing agent for complexing the plurality of Cu ions;
at least one pH adjuster;
at least one wetting agent for stabilizing the chemical solution, all being
dissolved in a volume of deionized (DI) water.

Claim 3 (currently amended): A method, as recited in Claim 2,

wherein the at least one zinc (Zn) ion source comprises at least one zinc salt
selected from a group consisting essentially of zinc acetate $((\text{CH}_3\text{CO}_2)_2\text{Zn})$, zinc bromide
 (ZnBr_2) , zinc carbonate hydroxide $(\text{ZnCO}_3 \cdot 2\text{Zn}(\text{OH})_2)$, zinc dichloride (ZnCl_2) , zinc
citrate $((\text{O}_2\text{CCH}_2\text{C}(\text{OH})(\text{CO}_2)\text{CH}_2\text{CO}_2)_2\text{Zn}_3)$, zinc iodide (ZnI_2) , zinc L-lactate
 $((\text{CH}_3\text{CH}(\text{OH})\text{CO}_2)_2\text{Zn})$, zinc nitrate $(\text{Zn}(\text{NO}_3)_2)$, zinc stearate $((\text{CH}_3(\text{CH}_2)_{16}\text{CO}_2)_2\text{Zn})$,
zinc sulfate (ZnSO_4) , zinc sulfide (ZnS) , zinc sulfite (ZnSO_3) , and their hydrates.

Claim 4 (currently amended): A method, as recited in Claim 2,

wherein the at least one copper (Cu) ion source comprises at least one copper salt
selected from a group consisting essentially of copper(I) acetate $(\text{CH}_3\text{CO}_2\text{Cu})$, copper(II)
acetate $((\text{CH}_3\text{CO}_2)_2\text{Cu})$, copper(I) bromide (CuBr) , copper (II) bromide (CuBr_2) , copper
(II) hydroxide $(\text{Cu}(\text{OH})_2)$, copper (II) hydroxide phosphate $(\text{Cu}_2(\text{OH})\text{PO}_4)$, copper(I)
iodide (CuI) , copper (II) nitrate $((\text{CuNO}_3)_2)$, copper(II) sulfate (CuSO_4) , copper(I) sulfide
 (Cu_2S) , copper(II) sulfide (CuS) , copper (II) tartrate $((\text{CH}(\text{OH})\text{CO}_2)_2\text{Cu})$, and their

Attorney Docket No.: 0180214

hydrates.

Claim 5 (original): A method, as recited in Claim 1.

wherein said electroplating step comprises using an electroplating apparatus, and
wherein said electroplating apparatus comprises:

- (a) a cathode-wafer;
- (b) an anode;
- (c) an electroplating vessel; and
- (d) a voltage source.

Claim 6 (currently amended): A method, as recited in Claim 5,

wherein the cathode-wafer comprises the Cu surface, and

wherein the anode comprises at least one material selected from a group consisting essentially of copper (Cu), a copper-platinum alloy (Cu-Pt), titanium (Ti), platinum (Pt), a titanium-platinum alloy (Ti-Pt), an anodized copper-zinc alloy (Cu-Zn, i.e., brass), a platinized titanium (Pt/Ti), and a platinized copper-zinc (Pt/Cu-Zn, i.e., platinized brass).

Claim 7 (canceled).

Claim 8 (currently amended): A method, as recited in Claim 5,

wherein said electroplating comprises a plating condition selected from a group

Attorney Docket No.: 0180214

consisting essentially of a direct voltage in the range of approximately 1 V to approximately 4 V and a direct current in the range of approximately 0.01 A to approximately 0.2 A.

Claim 9 (currently amended): A method, as recited in Claim 5,
wherein the Zn-doping in the reduced-oxygen Cu-Zn alloy thin film is controllable by varying at least one electroplating condition selected from a group consisting essentially of:

increasing the at least one zinc (Zn) ion source concentration, thereby slowly increasing said Zn-doping;

increasing the at least one copper (Cu) ion source concentration, thereby slowly decreasing said Zn-doping;

increasing the solution flow rate increases Zn-doping, thereby increasing the pH decreases cathodic efficiency with respect to Zn, and thereby decreasing said Zn-doping;

increasing the electroplating duration, thereby slowly decreasing said Zn-doping;

using a Cu anode, thereby decreasing said Zn-doping;

using a brass anode, thereby increasing said Zn-doping;

increasing the voltage, thereby increasing the Zn-doping; and

increasing the current, thereby increasing the Zn-doping.

Attorney Docket No.: 0180214

Claim 10 (original): A method, as recited in Claim 1,
wherein the annealing step is performed in a temperature range of approximately 150°C to approximately 450°C, and
wherein the annealing step is performed for a duration range of approximately 0.5 minutes to approximately 60 minutes.

Claim 11 (currently amended): A semiconductor device, having a reduced-oxygen copper-zinc alloy (Cu-Zn) thin film formed on a copper (Cu) surface by electroplating the Cu surface in a chemical solution, fabricated by a method comprising the steps of:

~~providing forming a semiconductor substrate having a Cu surface on a~~
semiconductor substrate;

providing a chemical solution;

electroplating the Cu surface in the chemical solution, thereby forming a Cu-Zn alloy thin film on the Cu surface, wherein the Cu-Zn alloy thin film completely covers the Cu surface;

rinsing the Cu-Zn alloy thin film in a solvent;

drying the Cu-Zn alloy thin film under a gaseous flow;

annealing the Cu-Zn alloy thin film formed on the Cu surface, thereby forming a reduced-oxygen Cu-Zn alloy thin film; and

completing formation of the semiconductor device.

Attorney Docket No.: 0180214

Claim 12 (original): A device, as recited in Claim 11,
wherein the chemical solution is nontoxic and aqueous, and
wherein the chemical solution comprises:

- at least one zinc (Zn) ion source for providing a plurality of Zn ions;
- at least one copper (Cu) ion source for providing a plurality of Cu ions;
- at least one complexing agent for complexing the plurality of Cu ions;
- at least one pH adjuster;
- at least one wetting agent for stabilizing the chemical solution, all being dissolved in a volume of deionized (DI) water.

Claim 13 (currently amended): A device, as recited in Claim 12,
wherein the at least one zinc (Zn) ion source comprises at least one zinc salt selected from a group consisting essentially of zinc acetate $((\text{CH}_3\text{CO}_2)_2\text{Zn})$, zinc bromide (ZnBr_2) , zinc carbonate hydroxide $(\text{ZnCO}_3 \cdot 2\text{Zn}(\text{OH})_2)$, zinc dichloride (ZnCl_2) , zinc citrate $((\text{O}_2\text{CCH}_2\text{C}(\text{OH})(\text{CO}_2)\text{CH}_2\text{CO}_2)_2\text{Zn}_3)$, zinc iodide (ZnI_2) , zinc L-lactate $((\text{CH}_3\text{CH}(\text{OH})\text{CO}_2)_2\text{Zn})$, zinc nitrate $(\text{Zn}(\text{NO}_3)_2)$, zinc stearate $((\text{CH}_3(\text{CH}_2)_{16}\text{CO}_2)_2\text{Zn})$, zinc sulfate (ZnSO_4) , zinc sulfide (ZnS) , zinc sulfite (ZnSO_3) , and their hydrates.

Claim 14 (currently amended): A device, as recited in Claim 12,
wherein the at least one copper (Cu) ion source comprises at least one copper salt

Attorney Docket No.: 0180214

selected from a group consisting essentially of copper(I) acetate ($\text{CH}_3\text{CO}_2\text{Cu}$), copper(II) acetate ($(\text{CH}_3\text{CO}_2)_2\text{Cu}$), copper(I) bromide (CuBr), copper (II) bromide (CuBr_2), copper (II) hydroxide ($\text{Cu}(\text{OH})_2$), copper (II) hydroxide phosphate ($\text{Cu}_2(\text{OH})\text{PO}_4$), copper(I) iodide (CuI), copper (II) nitrate ($(\text{CuNO}_3)_2$), copper(II) sulfate (CuSO_4), copper(I) sulfide (Cu_2S), copper(II) sulfide (CuS), copper (II) tartrate ($(\text{CH}(\text{OH})\text{CO}_2)_2\text{Cu}$), and their hydrates.

Claim 15 (original): A device, as recited in Claim 11,

wherein said electroplating step of said method comprises using an electroplating apparatus, and

wherein said electroplating apparatus comprises:

- (a) a cathode-wafer;
- (b) an anode;
- (c) an electroplating vessel; and
- (d) a voltage source.

Claim 16 (currently amended): A device, as recited in Claim 15,

wherein the cathode-wafer comprises the Cu surface, and

wherein the anode comprises at least one material selected from a group consisting essentially of copper (Cu), a copper-platinum alloy (Cu-Pt), titanium (Ti), platinum (Pt), a titanium-platinum alloy (Ti-Pt), an anodized copper-zinc alloy (Cu-Zn, i.e., brass), a

Attorney Docket No.: 0180214

platinized titanium (Pt/Ti), and a platinized copper-zinc (Pt/Cu-Zn, i.e., platinized brass).

Claim 17 (canceled).

Claim 18 (currently amended): A device, as recited in Claim 15,

wherein said electroplating comprises a plating condition selected from a group consisting essentially of a direct voltage in the range of approximately 1 V to approximately 4 V and a direct current in the range of approximately 0.01 A to approximately 0.2 A.

Claim 19 (currently amended): A device, as recited in Claim 15,

wherein the Zn-doping (i.e., Zn content) in the reduced-oxygen Cu-Zn alloy thin film is controllable by varying at least one electroplating condition selected from a group consisting essentially of:

increasing the at least one zinc (Zn) ion source concentration, thereby slowly increasing said Zn-doping;

increasing the at least one copper (Cu) ion source concentration, thereby slowly decreasing said Zn-doping;

increasing the solution flow rate increases Zn-doping, thereby increasing the pH decreases cathodic efficiency with respect to Zn, and thereby decreasing said Zn-doping;

increasing the electroplating duration, thereby slowly decreasing said Zn-doping;

Attorney Docket No.: 0180214

using a Cu anode, thereby decreasing said Zn-doping;
using a brass anode, thereby increasing said Zn-doping;
increasing the voltage, thereby increasing the Zn-doping; and
increasing the current, thereby increasing the Zn-doping.

Claim 20 (currently amended): A semiconductor device, having a reduced-oxygen copper-zinc alloy (Cu-Zn) thin film formed on a copper (Cu) surface, comprising:
a semiconductor substrate having at least one Cu surface formed thereon; and
a reduced-oxygen Cu-Zn alloy thin film formed, by electroplating, and disposed on the at least one Cu surface, wherein the reduced-oxygen Cu-Zn alloy thin film completely covers the at least one Cu surface,

wherein the reduced-oxygen Cu-Zn alloy thin film is formed by annealing a Cu-Zn alloy thin film in a temperature range of approximately 150°C to approximately 450°C,
and

wherein the reduced-oxygen Cu-Zn alloy thin film is formed by annealing a Cu-Zn alloy thin film for a duration range of approximately 0.5 minutes to approximately 60 minutes.